APPENDIX

DE19852159

MANUFACTURE OF FIBER-REINFORCED, OPTIONALLY NON-ROTATIONALLY SYMMETRICAL HOLLOW COMPOSITES WITH THERMOPLASTIC MATRIX, USING INTEGRATED EXTRUSION-PULTRUSION WINDING PLANT

The invention concerns a method for fiber impregnation and production of fiber-reinforced hollow bodies with a thermoplastic matrix, wherein the fiber impregnation takes place by means of an extruder, with a downstream sheathing nozzle, applied to a filament winding unit.

It is known that at present, the winding of fiber-reinforced composites with duroplastic matrix materials is at the forefront of the industrial manufacturing of winding bodies. Increasingly, applications for wound components with a thermoplastic matrix are being discovered in electrical engineering, construction, the automobile industry, and in plant and machine construction due to the advantages described by Funck (Development of innovative manufacturing techniques for the processing of continuously fiber-reinforced thermoplastics in winding methods, VDI-Fortschrittsberichte, Series 2; Fertigungstechnik, No.: 393) and the advantages described by Michaeli, Rau, and Jürss (Manufacturing of components in pultrusion and winding methods, Kunststoffberater 6/1995, pages 29-33), with reference to a possible lowering of costs by ca. 20%, good mechanical characteristics, and chemical resistance, reutilization capacity, and the omission of time-intensive curing. Application examples are pipes, shafts, tanks, or pressure vessels, so that the implementation of the winding process with thermoplastic matrix components has been pursued for some time.

An industrial and economic implementation has not yet been satisfactorily solved at present, so that on the one hand, efforts to improve the impregnation characteristics of the fiber material with the matrix component are being carried out and on the other hand, the qualities of the consolidation of the composite are increased by the use of suitable heater systems.

Among the known material modifications are impregnated or powder-impregnated fiber rovings (for example, FIT material glass fiber/polypropylene) and covered or twisted hybrid yarns (for example, Twintext roving by Vetrotex).

At the same time, the literature reports, in detail, regarding winding with an open flame by Funck, Neitzel, and Hausmann (Manufacture of thermoplastic pressure containers in the fiber winding method, Lecture 27. AVK Conference, Baden-Baden, 10/1996; Thermoplastic winding method for bicycle frames,

Kunststoffe 3/1995, pages 372-374), wherein, for example, cellulose or also natural fibers cannot be processed by means of this technological variant. Rosbach explains the conception and implementation of a thermoplastic winding method on the basis of an infrared heater system (Dissertation, ETH Zurich, 1995) and contact heating. The latter leads to the adhesion of the melt and to a cementing of the guide or consolidation elements, Born et al. (Winding with thermoplastic-impregnated fibers, Plastverarbeiter 5/1990, pages 18-25) and Neitzel et al. (Filament winding with thermoplastic matrices – current development & equipment, Japan International SAMPE Technical Seminar '94, Kyoto, July 14/15, 1994).

These energy transfers are limited because of the regulation, in particular, with rapid changes in the fiber winding rate--for example, in the turning zones.

The following patents describe only devices for the sheathing of a twisted cable (DE 40 03 735 A1), methods and devices for the crosslinking of polymers in the form of elongated winding material (DE 44 25 593 A1), and devices to produce a pipe by screw helix-shaped winding up (DE 31 45 122 Al).

The goal of the invention is to develop a suitable, simple, and economic method for the fiber impregnation and winding in the production of fiber-reinforced, also natural fiber-reinforced, hollow bodies with a thermoplastic matrix with a high product quality.

The goal, in accordance with the invention, is attained by the measures of Claim 1. Essentially, this is carried out by the combination of the filament winding technology with extrusion and pultrusion technology, a method variant for the online impregnation of continuous, but not necessarily continuous, windable, textile reinforcement semifinished products with thermoplastic matrices and thus the production of wound, thermoplastic fiber-plastic composites. The method for the production of wound hollow bodies with a thermoplastic matrix of drawing off, from a spool, semifinished thread products (roving, yarn, filament, sliver, fabric, etc.), which can be processed in a winding method, impregnating them in a sheathing nozzle with a thermoplastic melt supplied by a melt extruder, and laying them on a turning mold core.

The impregnation of the reinforcement semifinished products takes place, in the method in accordance with the invention, for the production of fiber-reinforced thermoplastic fiber-composite plastics in that the reinforcement semifinished products are supplied to a sheathing nozzle, operating according to the pultrusion principle (Figure 1, position 6), at the same time that the sheathing nozzle (6), adapted to a melt extruder (2), is supplied by it with the thermoplastic melt and the melt and reinforcement fiber or semifinished product are brought together. In addition to the mixing of fibers and matrix and/or the sheathing of the fibers by the matrix, an

online impregnation or preconsolidation takes place via pultrusion technology, in the sheathing nozzle (6), which preferably tapers in the production direction, so that the fiber-plastic composites produced according to the method of the invention have a high composite quality in comparison to previously used heater systems. The nozzle outlet is designed in such a way that a laying of the reinforcement semifinished product, impregnated thermoplastically in such a way, can take place on the rotating mold core and another introduction of energy by additional heater systems is not needed.

The method is thus a suitable, simple, and economic method, so as to impregnate, in one method step, the used reinforcement semifinished product with the thermoplastic matrix and to make possible the defined laying on a rotating mold core. The described method is particularly characterized by the production of a wound thermoplastic, fiber-plastic composite, with a high composite quality, as a result of the excellent impregnation of reinforcement with the matrix system.

The invention is described in more detail and explained below with the aid of the embodiment example shown in the drawing.

The pultrusion winding unit, shown in Figure 1, for the online impregnation of windable reinforcement semifinished products with a thermoplastic matrix, consisting of a melt extruder (2) with a filling funnel (3) and sheathing nozzle (6), found on the support (5) of a filament winding unit (1) with a winding core (4), is characterized by the defined and economical, high-quality impregnation of reinforcement materials with the melt supplied by the melt extruder (2) of the sheathing nozzle (6, Figure 2) and the laying, predefined by the prespecified fiber winding rate and the advance of the support (5), on the rotating winding core (4) of the filament winding unit (1).

The reinforcement system can be used in the pultrusion winding method, in accordance with the invention, in sliver, yarn, flyer or also hybrid flyer yarn and in roving form. Also, the use of textile fabric and mat semifinished products is possible, wherein as fiber materials, glass, plastic, aramid, carbon and/or natural fibers, for example, can be used.

<u>Example 1</u>

For the development of a new method technology by the combination of winding and extrusion processes for the production of rotation-symmetrical winding bodies, a hybrid flyer yarn, consisting of 50% thermoplastic and 50% natural fiber, open in its structure was produced in a first process step for the introduction of the matrix component into the composite.

To this end, flax and polypropylene staple fibers were used, wherein the production of the hybrid flyer yarn for the draw frame and flyer was carried out in

accordance with the cotton spinning method with a modified carding-cotton technology.

For the application of the fiber mixtures, the fiber components were placed in the mixing belt, mixed on a separator, and subsequently metered to a carding machine. Then, the thus produced fibrous pile arrived at a spinning can for the laying, via a flexibly connectable can coiler, before a formation to a sliver by means of a pressing roller pair was undertaken in another process step. With the aid of an additionally used cotton draw frame, the sliver was then doubled several times and distorted. The draw frame sliver produced in this manner was finally supplied to an extra-coarse flyer with an integrated 3-roller draw frame, rotated, and stretched to form a hybrid yarn.

It was subsequently possible to draw the hybrid yarn produced in such a way from a spool holder with a spool and supplied to the sheathing nozzle (6), found on the extruder (2). In the heated sheathing nozzle (6), the polypropylene fraction of the hybrid yarn was melted. Simultaneously, with the melt extruder (2) applied on the support (5) of the filament winding unit (1), additional polypropylene (ca. 20%) in granule form was added via a filling funnel (3), melted, and supplied to the sheathing nozzle (6). It was here that, on the one hand, the mixing of the two polypropylene components (fiber/granule) took place, and on the other hand, a mixing or sheathing of the flax fibers with polypropylene melt.

This process was intensified by the sheathing nozzle (6), tapering in the production direction, so that the thermoplastically impregnated natural fibers could be laid, via the nozzle outlet, on the winding core (4). By the adjustment of the fiber winding and support speed, in the range of 2-50 m/min, it was possible to produce winding bodies with a predefined pattern. Furthermore, it was possible to vary the fiber content from 10 to ca. 70 mass% of the wound hollow bodies via the throughput of the melt extruder (2).

Subsequently, the tubular specimens produced in the pultrusion winding method were subjected to a mechanical test in the compression test. The ascertained values for the compressive stress were compared with samples of the same starting materials, flax as the reinforcement fiber, and polypropylene as the matrix, which were wound at room temperature and subsequently consolidated in a press. This method variant in the thermoplastic winding technology makes possible an optimal composite consolidation as a result of the precise temperature control and the high applicable forces. The finally executed comparison of properties of the pultrusion winding method, in accordance with the invention, with the fiber winding at room temperature and the subsequent consolidation of the composite by means of

press technology did not exhibit a significant difference in the composite properties in the compression test.

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Claims of DE19852159

1. Method for the production of fiber-reinforced rotation but not necessarily rotation-symmetrical hollow bodies in the molding method with a thermoplastic matrix in a pultrusion winding unit (1), characterized in that the fiber impregnation takes place via a melt extruder (2), with a downstream sheathing nozzle (6), which is applied on a filament winding unit, wherein the reinforcement semifinished products are supplied to the sheathing nozzle (6), which is connected with the extruder (2) applied on the filament winding unit (1), and which are sheathed with the plastic melted via the extruder (2) with the filling funnel (3), in that by a tapering of the sheathing nozzle (6) in the production direction, the reinforcement semifinished product and the melted plastic are preconsolidated, and in that, then the reinforcement semifinished product, impregnated thermoplastically in such a way, is laid in a defined manner on the rotating mold core (4).

2. Method according to Claim 1, characterized in that diverse reinforcement systems in a sliver, tape, yarn, flyer, and/or hybrid flyer yarn and in roving form, or in other types of textile presentations or semifinished forms, such as a fabric or a mat semifinished product, are used.

3. Method according to Claims 1 and 2, characterized in that continuous and/or discontinuous fibrous materials, such as glass, carbon, or aramid fibers and, for example, flax, hemp, nettle, jute, and sisal fibers, are used individually or in a mixture.

4. Method according to Claims 1-3, characterized in that thermoplastics are preferably supplied in the granule form and melted, via the melt extruder (2) with a filling funnel (3) or another melt unit.

5. Method according to Claims 1-4, characterized in that to bring the melt and the reinforcement semifinished product, the sheathing nozzle (6) is adapted to the melt extruder (2) or another melt unit.

6. Method according to Claims 1-5, characterized in that the melt extruder (2) or the other melt unit with adapted sheathing nozzle (6) is applied on the support (5) of the filament winding unit (1) and a predifined winding pattern is produced by a defined rotation of the winding core (4) and the method of the support (5).

7. Method according to Claims 1-6, characterized in that the impregnated, preconsolidated semifinished product is laid, in a melt-shaped state, on a rotating positive or negative winding core (4).